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Kai et al.

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(54) **METHOD FOR FABRICATING STACKED NITRIDE-COMPOUND SEMICONDUCTOR STRUCTURE AND METHOD FOR FABRICATING NITRIDE-COMPOUND SEMICONDUCTOR LIGHT EMITTING DEVICE**

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H01L 21/02 (2006.01)
H01L 33/00 (2010.01)

(52) **U.S. Cl.**

CPC ***H01L 21/0254*** (2013.01); ***H01L 21/02381*** (2013.01); ***H01L 21/02433*** (2013.01); ***H01L 21/02458*** (2013.01); ***H01L 21/0262*** (2013.01); ***H01L 21/02658*** (2013.01); ***H01L 33/007*** (2013.01)

USPC **438/47**; 438/46; 438/94

(58) **Field of Classification Search**

USPC 438/46, 47, 94

See application file for complete search history.

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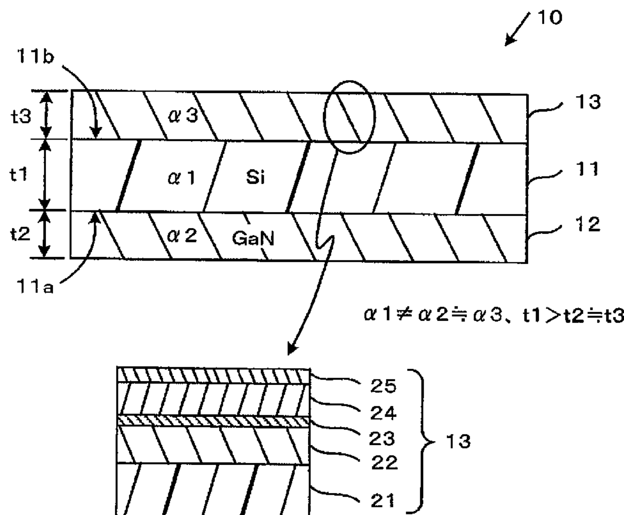
(57) **ABSTRACT**

According to one embodiment, a method for fabricating a stacked nitride-compound semiconductor structure includes forming a first protection film on a second surface of a substrate, forming a first nitride-compound semiconductor layer on the first surface of the substrate, forming a second protection film on the first nitride-compound semiconductor layer, removing the first protection film to expose the second surface of the substrate, forming a second nitride-compound semiconductor layer on the second surface of the substrate, and removing the second protection film to expose the first surface of the second nitride-compound semiconductor layer.

19 Claims, 10 Drawing Sheets



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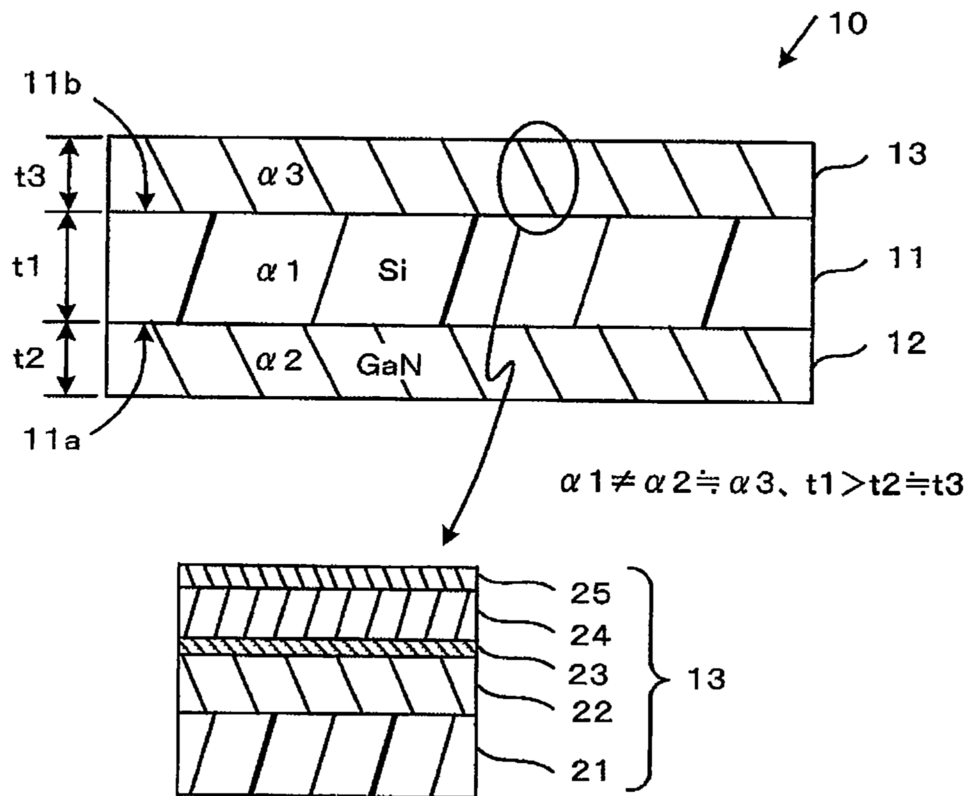


FIG. 1

FIG.2A

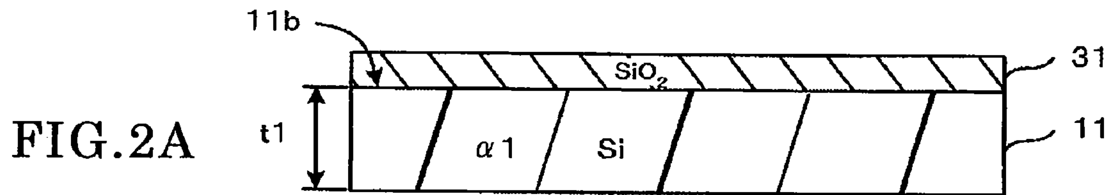


FIG.2B

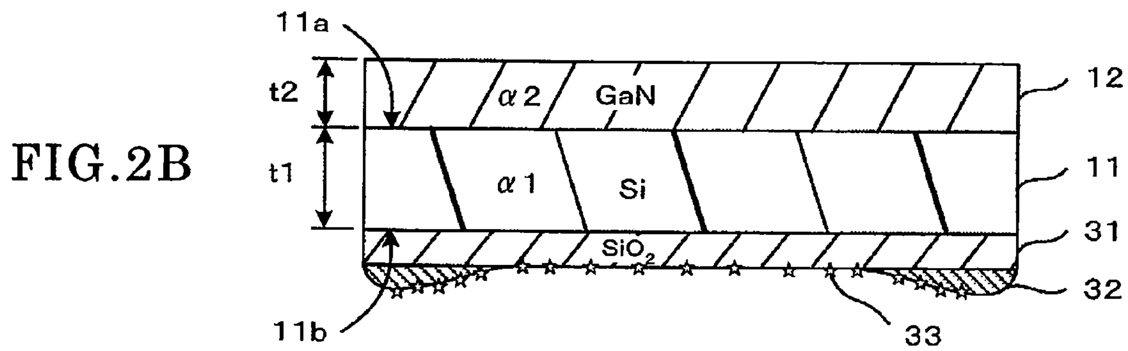


FIG.2C

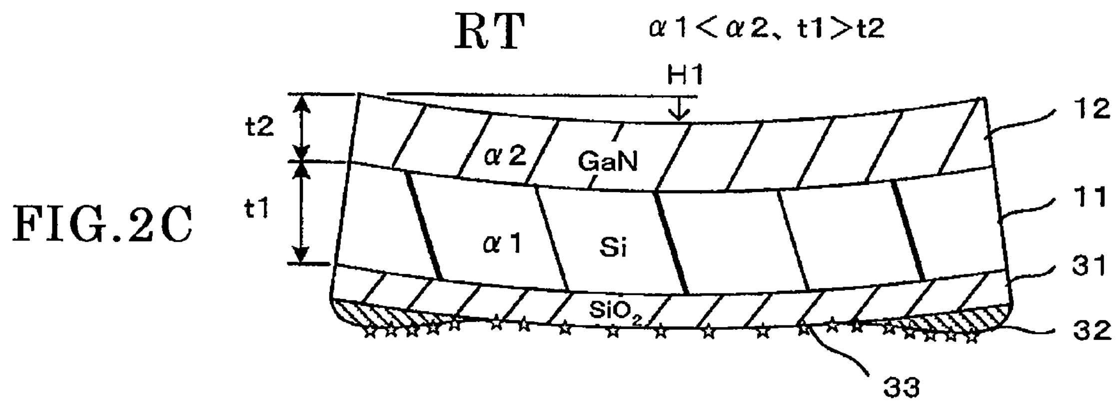


FIG.3A

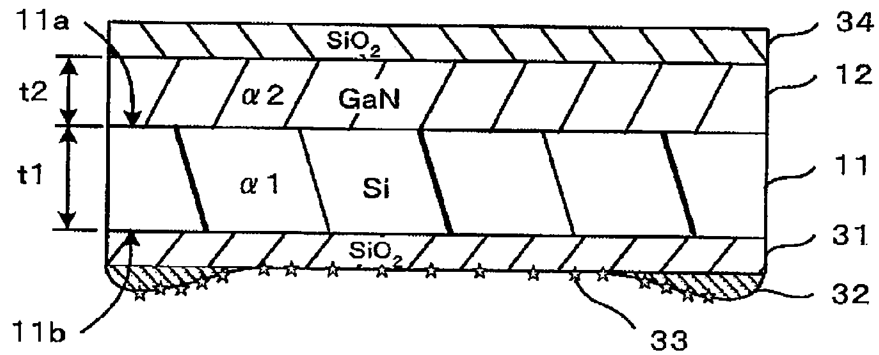


FIG.3B

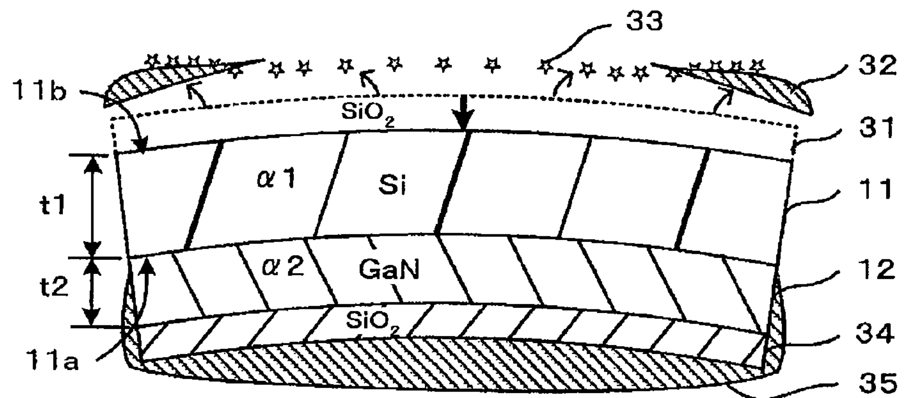
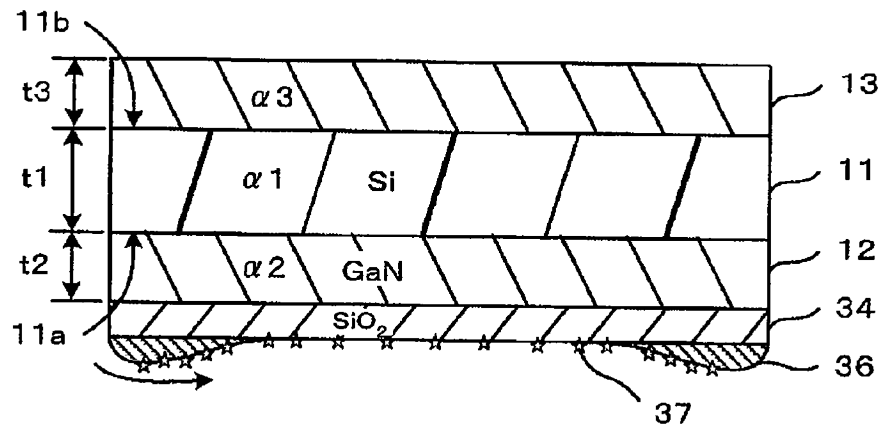


FIG.3C



RT

$\alpha 2 \fallingdotseq \alpha 3$、$t2 \fallingdotseq t3$

FIG.4A

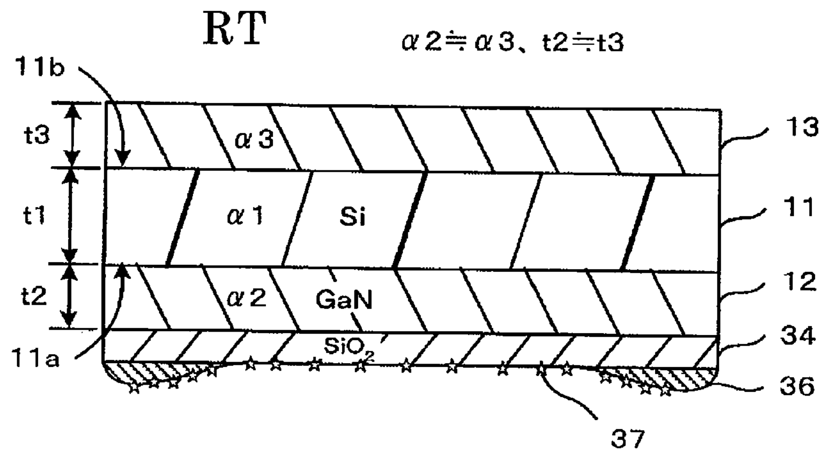
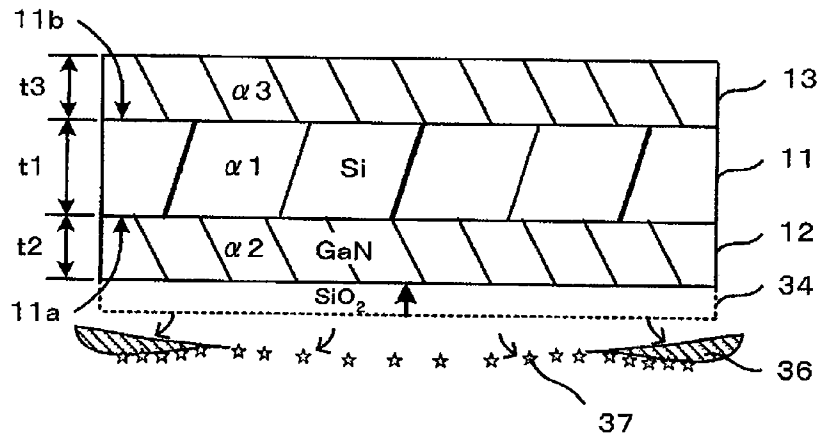


FIG.4B



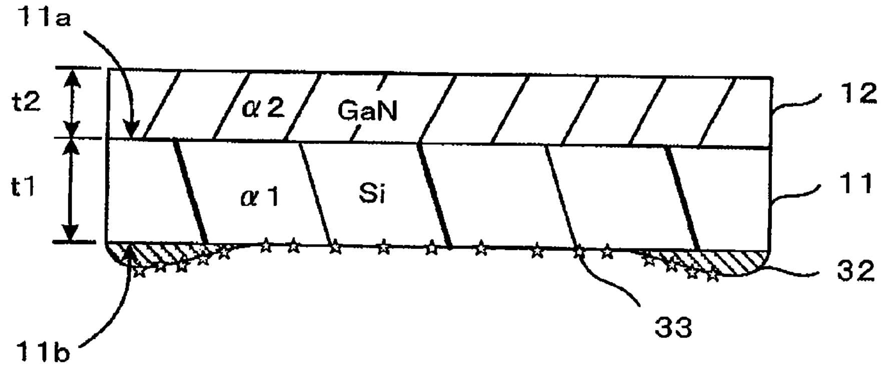


FIG.5A

RT α1<α2、t1>t2

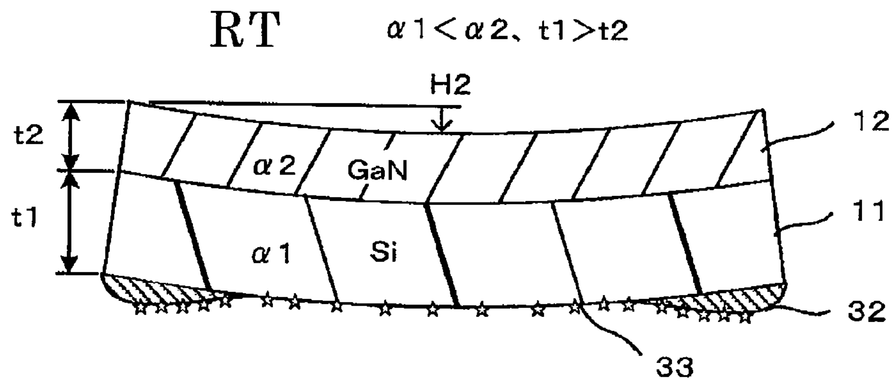


FIG.5B

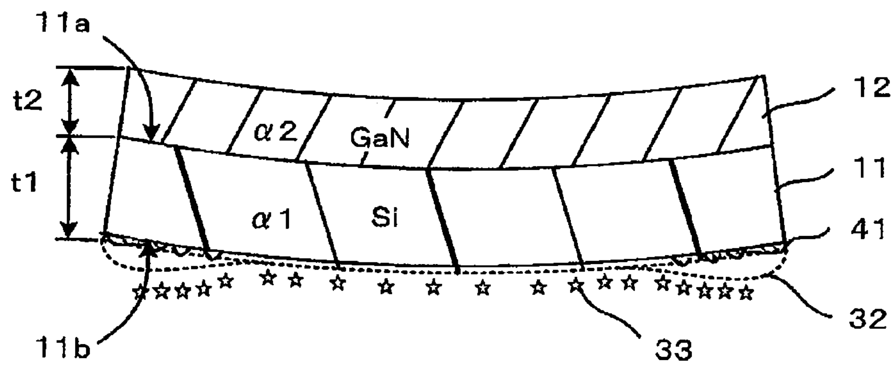
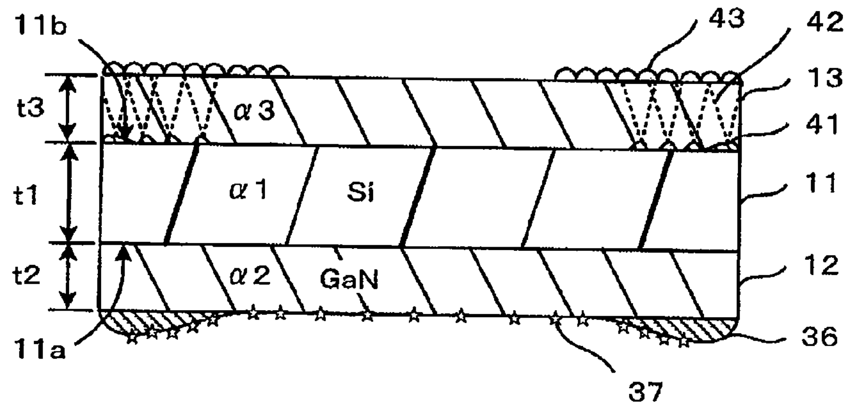


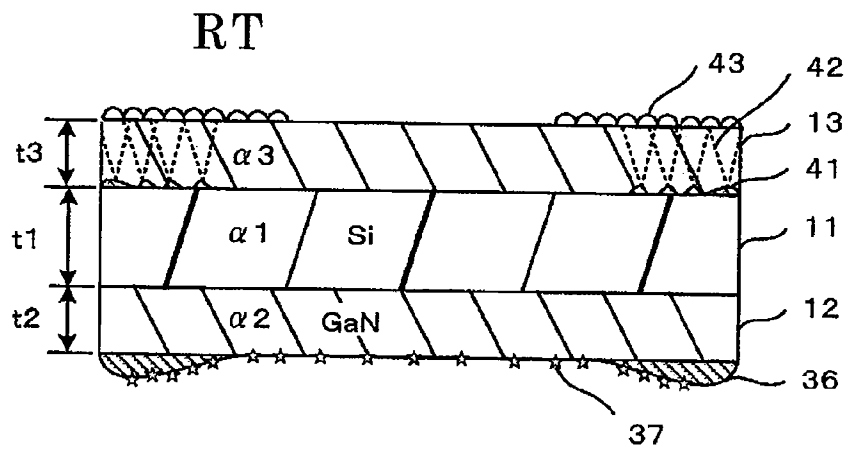
FIG.5C

FIG.6A



RT

FIG.6B



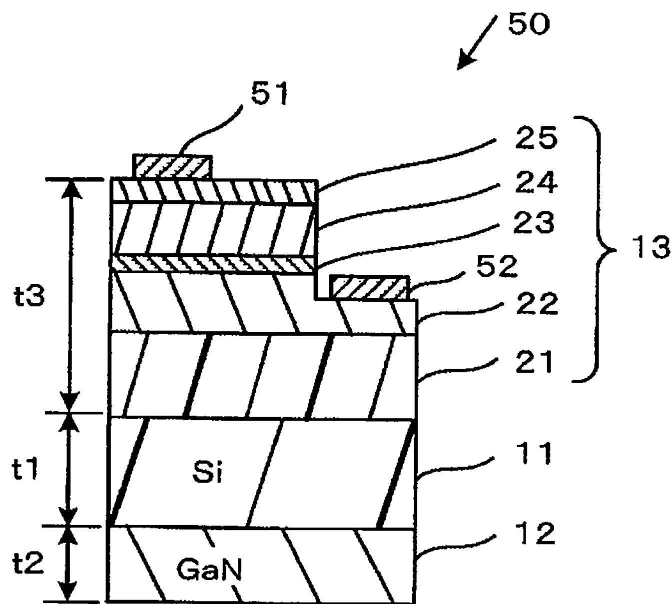


FIG. 7

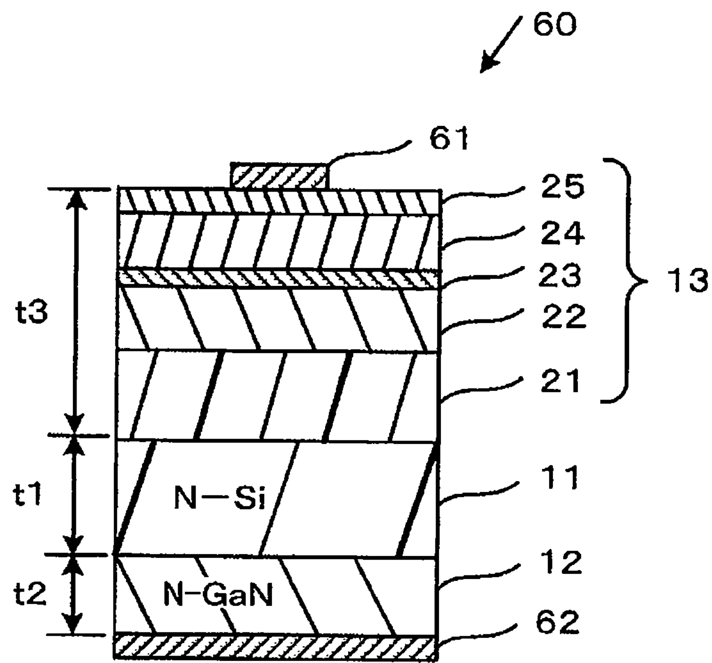


FIG.8

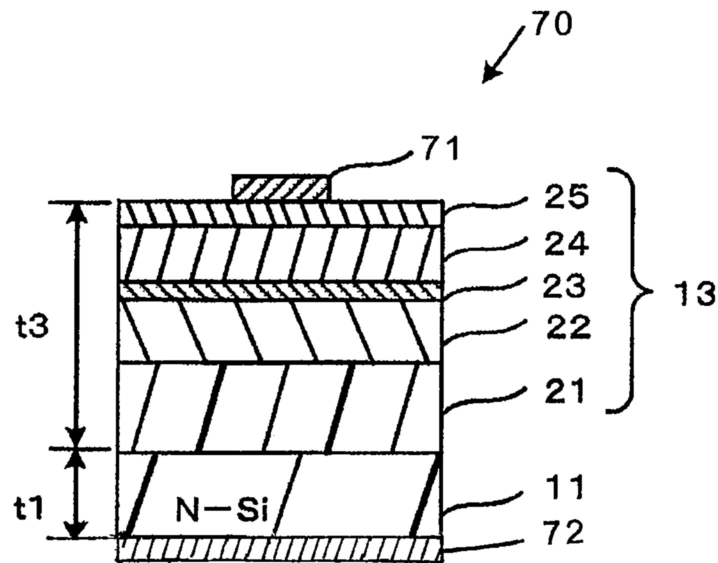


FIG.9

FIG.10A

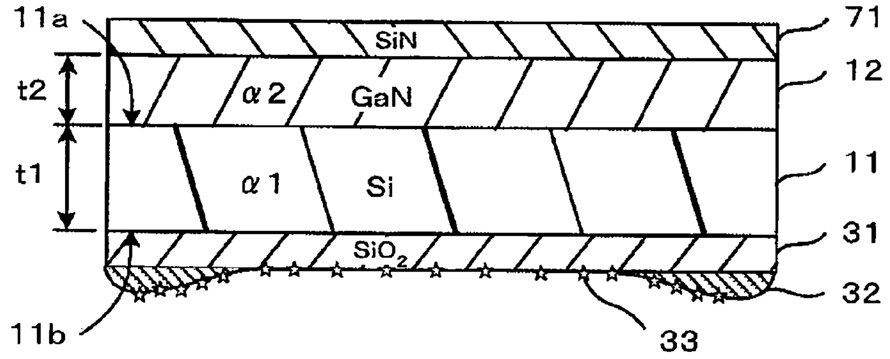


FIG.10B

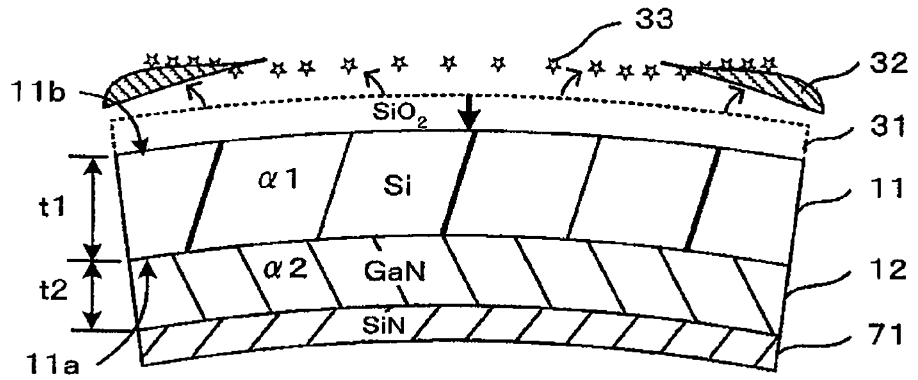
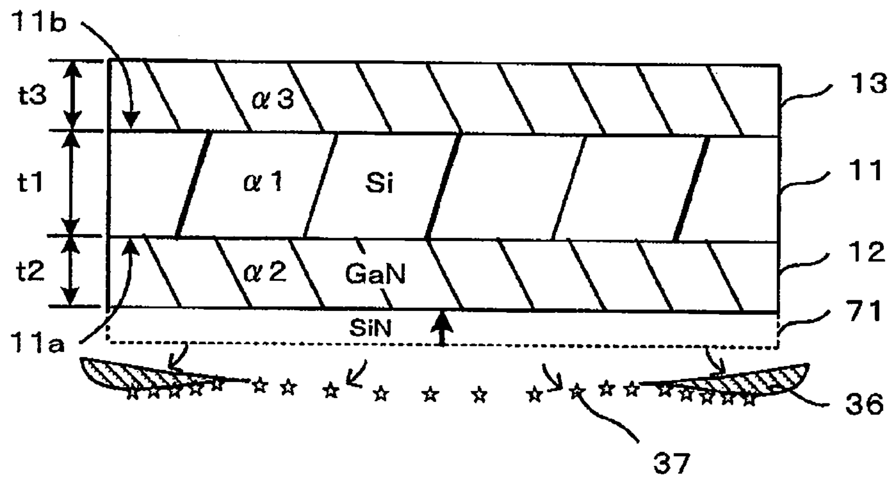


FIG.10C



METHOD FOR FABRICATING STACKED NITRIDE-COMPOUND SEMICONDUCTOR STRUCTURE AND METHOD FOR FABRICATING NITRIDE-COMPOUND SEMICONDUCTOR LIGHT EMITTING DEVICE

CROSS REFERENCE TO RELATED APPLICATION

This application is based upon and claims the benefit of priority from prior Japanese Patent Application No. 2011-200511, filed on Sep. 14, 2011, the entire contents of which are incorporated herein by reference.

FIELD

Exemplary embodiments described herein generally relate to a method for fabricating a stacked nitride-compound semiconductor structure and a method for fabricating a nitride-compound semiconductor light emitting device.

BACKGROUND

Different kinds of substrates such as a sapphire substrate, a silicon substrate or the like are used as a substrate to grow a nitride-compound semiconductor.

Thermal expansion coefficient of the nitride-compound semiconductor is different from that of the different kind of each substrate. Therefore, warpage is generated in the stacked nitride-compound semiconductor structure which is constituted with nitride-compound semiconductors on the different kind of the substrate.

Conventionally, a stacked nitride-compound semiconductor structure mentioned below has been well known. Nitride-compound semiconductor layers with an active layer and another nitride-compound semiconductor layer are provided on a surface and a back surface of the substrate, respectively, in the stacked nitride-compound semiconductor structure.

Such the stacked nitride-compound semiconductor structure is fabricated as follows to decrease the warpage. First, the nitride-compound semiconductor layer is formed on the back surface of the substrate. Next, the nitride-compound semiconductor layers with the active layer are formed on the surface of the substrate.

In the processing steps to provide the nitride-compound semiconductor layer on the back surface of the substrate, process gas is penetrated into a side of the surface of the substrate. Further, deposition substances are attached to an outer periphery portion of the surface of the substrate. When the deposition substances remain, crystalline defects are generated in the nitride-compound semiconductor layers with the active layer so as to degrade device characteristics and device yield.

Accordingly, it is necessary to remove the deposition substances on the substrate without damage to the surface of the substrate prior to form the nitride-compound semiconductor layers with the active layer on the substrate.

However, nitride-compound semiconductor has a strong resistance to chemicals. As a result, there arises a problem that the deposition substances cannot be sufficiently removed to leave residues.

When the different kind of the substrate is composed of silicon, especially, there arises a problem that even retaining flatness of a surface of the substrate is difficult, as silicon is strongly reacted with gallium.

It is considered that the surface of the silicon substrate is polished again. However, the stacked nitride-compound semiconductor structure has warpage in this step. Therefore, the structure has difficulty even in retaining the flatness of the surface of the substrate.

Furthermore, warpage is proportional to square of a diameter. When a substrate with larger diameter is used in the process, more severe problem may be generated.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a cross-sectional view showing a stacked nitride-compound semiconductor structure according to a first embodiment;

FIGS. **2**A-**2**C are cross-sectional views showing a method for fabricating the stacked nitride-compound semiconductor structure in order according to the first embodiment;

FIGS. **3**A-**3**C are cross-sectional views showing the method for fabricating the stacked nitride-compound semiconductor structure in order according to the first embodiment;

FIGS. **4**A-**4**B are cross-sectional views showing the method for fabricating the stacked nitride-compound semiconductor structure in order according to the first embodiment;

FIGS. **5**A-**5**C are cross-sectional views showing a method for fabricating a stacked nitride-compound semiconductor structure in order according to a comparative example;

FIG. **6**A-**6**B are cross-sectional views showing the method for fabricating the stacked nitride-compound semiconductor structure in order according to the comparative example;

FIG. **7** is a cross-sectional view showing a nitride-compound semiconductor light emitting device constituted in a stacked nitride-compound semiconductor structure according to the first embodiment;

FIG. **8** is a cross-sectional view showing a nitride-compound semiconductor light emitting device constituted in a stacked nitride-compound semiconductor structure according to the first embodiment;

FIG. **9** is a cross-sectional view showing a nitride-compound semiconductor light emitting device constituted in a stacked nitride-compound semiconductor structure according to the first embodiment;

FIG. **10**A-**10**C are cross-sectional views showing main processes of a method for fabricating a stacked nitride-compound semiconductor structure in order according to a second embodiment.

DETAILED DESCRIPTION

According to one embodiment, a method for fabricating a stacked nitride-compound semiconductor structure includes forming a first protection film on a second surface of a substrate having a first thermal expansion coefficient, the second surface configured to be opposed to a first surface of the substrate, forming a first nitride-compound semiconductor layer on the first surface of the substrate, the first nitride-compound semiconductor layer having a second thermal expansion coefficient which is different from the first thermal expansion coefficient, forming a second protection film on the first nitride-compound semiconductor layer, removing the first protection film to expose the second surface of the substrate, forming a second nitride-compound semiconductor layer on the second surface of the substrate, the second nitride-compound semiconductor layer having a third thermal expansion coefficient which is approximately equal to the second thermal expansion coefficient, and removing the sec-

ond protection film to expose a surface the second nitride-compound semiconductor layer.

Hereinbelow, embodiments will be described with reference to the drawings.

First Embodiment

A method for fabricating the stacked nitride-compound semiconductor structure according to a first embodiment is explained by using FIG. **1**-FIGS. **4**A-4C. FIG. **1** is a cross-sectional view showing a stacked nitride-compound semiconductor structure according to the first embodiment. FIGS. **2**-**4** are cross-sectional views showing the method for fabricating the stacked nitride-compound semiconductor structure in order according to the first embodiment;

The stacked nitride-compound semiconductor structure according to the first embodiment is used as a production for a nitride-compound semiconductor light emitting device. Nitride-compound semiconductor layers are formed on both surfaces of a different kind of a substrate to balance stress caused by difference between thermal expansion coefficients of the nitride-compound semiconductor layers formed on both surfaces. Accordingly, warpage of the substrate can be decreased.

As shown in FIG. **1**, a substrate **11** has a first surface **11***a* and a second surface **11***b* opposed to the first surface **11***a* in the stacked nitride-compound semiconductor structure of the first embodiment. Further, the stacked nitride-compound semiconductor structure **10** has first thermal expansion coefficient α**1**.

A first nitride-compound semiconductor layer **12** is provided on the first surface **11***a* of the substrate **11**. The first nitride-compound semiconductor layer **12** has second thermal expansion coefficient α**2** which is different from the first thermal expansion coefficient α**1**. A second nitride-compound semiconductor layer **13** is provided on the second surface **11***b* of the substrate **11**. The second nitride-compound semiconductor layer **13** has third thermal expansion coefficient α**3** which is nearly equal to the second thermal expansion coefficient α**2**.

The substrate **11** has a diameter of nearly 150 mm and a thickness t**1** of nearly 500 μm, for example. The first thermal expansion coefficient al of the substrate **11** is nearly 2.4×10^{-6}/K.

The first nitride-compound semiconductor layer **12** is constituted with a gallium nitride (GaN) layer which has a thickness t**2** of nearly 5 μm, for example. The first nitride-compound semiconductor layer **12** has the second thermal expansion coefficient α**2** of nearly 3.17×10^{-6}/K.

The second nitride-compound semiconductor layer **13** is a stacked structure which is sequentially constituted with a GaN layer **21**, an n-type GaN clad layer **22**, an MQW layer **23**, a p-type GaN clad layer **24** and a p-type GaN contact layer **25**.

As the second nitride-compound semiconductor layer **13** has been well known, an explanation is simply described below. The GaN layer **21** is an underlying single crystalline layer to grow from the n-type GaN clad layer **22** to the p-type GaN contact layer **25**. The GaN layer **21** has a thickness of 3 μm, for example, which is comparatively thicker. The n-type GaN clad layer **22** has a thickness of nearly 2 μm, for example.

The MQW layer **23** is alternately stacked with seven GaN barrier layers and seven InGaN quantum well layers as a multiple quantum well structure and the topmost layer of the MQW layer **23** is constituted with the InGaN quantum well layer. Each of the GaN barrier layers has a thickness of nearly 5 nm and each of the InGaN quantum well layers has a thickness of nearly 2.5 nm.

The p-type GaN clad layer **24** is formed to have a thickness of nearly 100 nm, for example, and the p-type GaN contact layer **25** is formed to have a thickness of nearly 10 nm, for example.

An indium composition ratio x of the InGaN quantum well layer (In_xGa_{1-x} layer, $0\leq x\leq1$) is set to be nearly 0.1, in such a manner a peak wave length of emission light from the second nitride-compound semiconductor layer **13** set at 450 nm, for example.

The second nitride-compound semiconductor layer **13** has a thickness t**3** of nearly 5.16 μm which is almost occupied by the GaN layer **21** and the n-type GaN clad layer **22**.

A method for fabricating a stacked nitride-compound semiconductor structure **10** is described below. First, a second nitride-compound semiconductor layer **12** is formed on a first surface **11***a* of a substrate **11** in the method for fabricating the stacked nitride-compound semiconductor structure **10** according to the first embodiment. Successively, a second nitride-compound semiconductor layer **13** is formed on a second surface **11***b*. Processing steps are constructed to easily remove deposition substances which are attached to one surface opposed to the other surface on which the nitride-compound semiconductor layer is formed.

In such a manner, generation of crystalline defects in the second nitride-compound semiconductor layer **13** due to the deposition substances formed at the side of the second surface **11***b* are protected. Further, flatness degradation of the substrate **11** due to the deposition substances on the first surface is prevented. Accordingly, degradation of device characteristics and lowering of device yield on device fabrication are prevented.

As shown in FIG. **2**A, a silicon substrate with a plane orientation (111) ±2° is used as the substrate **11**. A silicon oxide film is formed on the second surface **11***b* of the substrate **11** as the first protection film **31**, for example, by CVD.

The first protection film **31** is provided to prevent the deposition substances from directly attaching to the second surface **11***b* and to easily remove the deposition substances from the substrate **11**. It is preferable to use a dense film and to have a thickness of 100-300 nm as the first protection film **31**.

As shown in FIG. **2**B, the substrate **11** is reversed. The first nitride-compound semiconductor layer **12** with a thickness of nearly 5 μm is provided on the first surface **11***a* of the substrate **11** by MOCVD (Metal Organic Chemical Vapor Deposition).

In the processing step, process gas is penetrated into a side of the second surface **11***b* of the substrate **11**. Further, the deposition substances **32** and the particles **33** are attached to an outer periphery portion of the first protection film **31**. The deposition substances **32** and the particles **33** are mainly composed of polycrystalline GaN.

As the second surface **11***b* of the substrate **11** is covered with the first protection film **31**, the deposition substances **32** and the particles **33** are not attached on the second surface **11***b* of the substrate **11**. As the substrate **11** is retained at a growth temperature, therefore, the substrate **11** has not warpage.

FIG. **2**C shows the substrate **11** at room temperature. Warpage H**1** is generated in the substrate **11** at room temperature due to a difference of thermal expansion coefficient between Si and GaN, so that the side of the first nitride-compound semiconductor layer **12** deforms to be concave.

As a method of providing the GaN layer on the silicon substrate is well-known, an explanation is simply described below. After cleaning the silicon substrate by organic material or acid material as pre-treatment, the silicon substrate is installed in a reactor of an MOCVD apparatus.

Next, the silicon substrate is heated up to 1100° C. in hydrogen gas ambient, for example. In such a manner, the surface of the silicon substrate is etched in gas-phase, so that a natural silicon oxide formed on the surface is removed.

An Al-nitride (AlN) buffer layer is formed on the silicon substrate by supplying NH_3 gas and Tri-methyl Aluminum (TMA) gas as process gases, for example, and a mixed gas of N_2 gas and H_2 gas as a carrier gas.

Next, the temperature of the silicon substrate is lowered down to 1050° C., for example. A GaN layer is formed on the AlN buffer layer by supplying NH_3 gas and Tri-methyl Gallium (TMG) gas as the process gases, for example, and the mixed gas of N_2 gas and H_2 gas as the carrier gas.

Further, the NH_3 gas and the carrier gas is continuously supplying while the TMG gas is stopped to be supplied, and the temperature of the silicon substrate is spontaneously lowered. Further, the NH_3 gas is continuously supplied till the temperature of the silicon substrate is lowered down to 500° C.

As shown in FIG. **3**A, a silicon oxide film is formed on the first nitride-compound semiconductor layer **12** as a second protection film **34** by CVD.

The second protection film **34** is provided to prevent the deposition substances from directly being deposited on the first nitride-compound semiconductor layer **12**. A thickness of the second protection film **34** is suitably set to be nearly the same as the thickness of the first protection film **31**.

As shown in FIG. **3**B, the first protection film **31** is removed after covering a surface and side surfaces of the second protection film **34** by a third protection film **35**. In such a manner, the second surface **11***b* of the substrate is exposed.

A removal process of the first protection film **31** is conducted by using a chemical solution with hydrogen fluoride, for example. A wax such as paraffin is suitable as the third protection film **35**.

In the removal process, the deposition substances **32** and particles **33** are not etched by the chemical solution. On the other hand, the first protection film **31** under the deposition substances **32** and particles **33** is side-etched to force the deposition substances **32** and particles **33** to float on the chemical solution from the substrate.

As a result, the deposition substances **32** and particles **33** can be removed without damages to the second surface **11***b* of the substrate **11**.

As shown in FIG. **3**C, the second nitride-compound semiconductor layer **13** is formed on the second surface **11***b* of the silicon substrate after removing the third protection film by an organic chemical solution.

In the processing step, the process gas is penetrated into a side of the first surface **11**A of the substrate **11**, further, deposition substances **36** and particles **37** are attached to an outer periphery portion of the second protection film **34**. The deposition substances **36** and the particles **37** are mainly composed of polycrystalline GaN.

As the first nitride-compound semiconductor layer on the substrate **11** is covered with the second protection film **34**, the deposition substances **36** and the particles **37** are not attached on the first nitride-compound semiconductor layer. As the substrate **11** is retained at a growth temperature, therefore, the substrate **11** is not warpage.

FIG. **4**A shows a state of the substrate **11** in room temperature. Stress caused by difference of thermal expansion coefficient between silicon and GaN is decreased by forming the first nitride-compound semiconductor layer and the second nitride-compound semiconductor layer on the first surface and the second surface of the silicon substrate, respectively, to decrease the warpage of the silicon substrate in room temperature.

As the method for fabricating the second nitride-compound semiconductor layer **13** has been well known, an explanation is simply described below. A GaN layer with a thickness of 3 μm is formed by the same process as shown in FIG. **2**B.

An n-type GaN clad layer **22** with a thickness of 2 μm is formed by adding SiH_4 gas, for example, as a source gas of n-type impurities to the process gas. Successively, the NH_3 gas is continuously supplied while the SiH_4 gas and the TMG gas are stopped to be supplied, and the temperature of the substrate **11** is lowered down to below 1100° C., for example, 800° C. and is retained at 800° C.

A GaN barrier layer with a thickness of 5 nm is formed on the n-type GaN clad layer by using N_2 gas as a carrier gas and NH_3 gas as a process gas, for example. Further, an InGaN quantum-well layer with a thickness of 2.5 μm and an indium composition ratio of 0.1 is formed by adding Tri-methyl Indium (TMI) gas in the carrier gas and the process gas.

Forming the GaN barrier layer and forming the InGaN quantum-well layer are repeated seven times by intermittently supplying the Tri-methyl Indium gas to obtain an MQW layer **23**.

Successively, the TMG gas and the SiH_4 gas are continuously supplied while the TMI gas is stopped to be supplied to form an undoped GaN cap layer with a thickness of 5 nm.

Further, the SiH_4 gas is continuously supplied while the TMG gas is stopped to be supplied, and the temperature of the substrate **11** is heated up to over 800° C., for example, 1030° C. and is retained at 1030° C.

A p-type GaN clad layer **24** with a magnesium concentration of 1×10^{20} cm^{-3} and a thickness of nearly 100 nm is formed on the MQW layer **23** by supplying NH_3 gas and TMG gas as process gases, for example, biscyclopentadienyl magnesium (Cp2Mg) gas as a doping gas and mixed gas of N_2 gas and H_2 gas as carrier gases.

Next, the Cp2Mg gas is increased to form a p-type GaN contact layer **25** with a magnesium concentration of 1×10^{21} cm^{-3} and a thickness of nearly 10 nm on the p-type GaN clad layer **24**.

The NH_3 gas and the carrier gases are continuously supplied while the NH_3 gas and the Cp2Mg gas are stopped to be provided, and the temperature of the silicon substrate **11** is spontaneously lowered. The NH_3 gas is continuously supplied till the temperature of the silicon substrate **11** is lowered down to 500° C.

In such a manner, the second nitride-compound semiconductor layer **13** is formed on the second surface **11***b* of the substrate **11** and the p-type GaN contact layer **25** is constituted as a surface of the second nitride-compound semiconductor layer **13**.

As shown in FIG. **4**B, the second protection film **34** is removed to expose the first nitride-compound semiconductor layer **12**. The second protection film **34** is removed by using a chemical solution with hydrogen fluoride as the same method as removing the first protection film.

In the removal process, the deposition substances **36** and particles **37** are not etched by the chemical solution. On the other hand, the second protection film **34** under the deposition substances **36** and particles **37** is side-etched to force the deposition substances **36** and particles **37** to float on the chemical solution from the substrate.

As a result, the deposition substances **36** and particles **37** can be simultaneously removed with the second protection film **34** without damages to the first surface **11***a* of the silicon substrate.

In such a manner, the stacked nitride-compound semiconductor structure **10** in which the first nitride-compound semiconductor layer **12** is formed on the first surface **11***a* of the substrate **11** and the second nitride-compound semiconductor layer **13** is formed on the second surface **11***b* of the substrate **11** as shown in FIG. **1**.

As stress caused by difference of thermal expansion coefficient between the first surface side and the second surface side of the silicon substrate is balanced, the warpage of the silicon substrate in room temperature can be decreased.

Comparative Example

Next, a method for fabricating a stacked nitride-compound semiconductor structure according to a comparative example is described with reference to drawings. FIGS. **5**A-**5**C and FIGS. **6**A-**6**C are cross-sectional views showing the method for fabricating the stacked nitride-compound semiconductor structure according to the comparative example.

Processing steps of forming a first protection film **31** and a second protection film **34** are not included in the method for fabricating the stacked nitride-compound semiconductor structure according to the comparative example.

As shown in FIG. **5**, a first nitride-compound semiconductor layer **12** is formed on a first surface **11***a* of a substrate **11** as the same as the process shown in FIG. **2**.

In the processing step, process gas is penetrated into a side of the second surface **11***b* of the substrate **11**. Further, the deposition substances **32** and the particles **33** are attached to an outer periphery portion of the second surface **11***b* of the substrate **11**. As the substrate **11** is retained at a growth temperature, therefore, the substrate is not warpage in this stage.

On the other hand, Si is strongly reacted with Ga in the process gas. Accordingly, reaction products between Si and Ga other than polycrystalline GaN are included in the deposition substances **32**.

FIG. **5**B shows the substrate **11** at room temperature. Warpage H**2** is generated in the substrate **11** at room temperature due to difference of thermal expansion coefficient between Si and GaN, so that the side of the first nitride-compound semiconductor layer **12** deforms to be concave. The warpage H**2** is nearly equal to the warpage H**1** shown in FIG. **2**C.

As shown in FIG. **5**C, the second surface **11***b* of the substrate **11** is etched by a chemical solution with hydrogen fluoride and nitric acid, for example.

In the removal process, the deposition substances **32** and the particles **33** are not etched by the chemical solution. On the other hand, Si under the deposition substances **32** and particles **33** is side-etched to force the deposition substances **32** and particles **33** to float on the chemical solution from the substrate.

On the other hand, the reaction products between Si and Ga are included in the deposition substance **32**. Therefore, the deposition substances **32** are not sufficiently removed, so that residues **41** are generated. When the substrate **11** is continuously etched, the substrate **11** under the residues **41** is grooved to generate concavity and convexity in the substrate **11**. Therefore, it is difficult to retain flatness of the substrate **11**.

As a result, the removal of the deposition substances **32** and particles **33** without damages to the second surface **11***b* of the substrate **11** become difficult.

For securing flatness, the second surface **11***b* of the substrate **11** may be polished again by chemical mechanical polishing (CMP). However, the substrate **11** has warpage in this step, therefore, the substrate **11** may be damaged in polishing.

Furthermore, warpage is proportional to square of diameter. When a substrate with larger diameter is used in the process, more severe problem may be generated.

As shown in FIG. **6**A, the substrate **11** is reversed. The second nitride-compound semiconductor layer **13** is provided on the second surface **11***b* of the substrate **11** as the same process as shown in FIG. **3**C.

In the deposition process, crystalline defects are generated in the second nitride-compound semiconductor layer **13** caused by the residues **41** on the second surface **11***b* of the substrate **11**. As the second nitride-compound semiconductor layer **13** becomes thicker, white turbidities are generated on the surface of the second nitride-compound semiconductor layer **13** to deteriorate surface morphology.

When a nitride-compound semiconductor light emitting device is provided in the second nitride-compound semiconductor layer **13**, device characteristics and device yield are degraded.

In the processing step, the process gas is penetrated into a side of the first surface **11***a* of the substrate **11**. Further, deposition substances **36** and particles **37** are attached to an outer periphery portion of the first nitride-compound semiconductor layer **12**. The deposition substances **36** and the particles **37** are mainly composed of polycrystalline GaN.

The deposition substances **36** are composed of GaN which is the same as the deposition substances **32** on the first surface **11***a* of the substrate **12** and are not sufficiently removed to degrade flatness of the substrate **11**.

For securing flatness, the nitride-compound semiconductor layer **12** may be polished by CMP. As mentioned after, warpage of the substrate **11** is decreased, the nitride-compound semiconductor layer **12** can be polished. However, processing steps are increased as a problem.

FIG. **6**B shows a state of the substrate **11** in room temperature. Stress caused by difference of thermal expansion coefficient between silicon and GaN is decreased by forming the first nitride-compound semiconductor layer and the second nitride-compound semiconductor layer on the first surface and the second surface of the silicon substrate, respectively, to decrease the warpage of the silicon substrate in room temperature.

As mentioned above, it is difficult that the deposition substances **32** which is generated by penetration of the process gas to the back surface are sufficiently removed. Accordingly, the stacked nitride-compound semiconductor structure **10** as shown in FIG. **1** cannot be obtained.

Next, a method for fabricating a nitride-compound semiconductor light emitting device in a stacked nitride-compound semiconductor structure is described. FIG. **7** is a cross-sectional view showing a nitride-compound semiconductor light emitting device constituted in the stacked nitride-compound semiconductor structure according to the first embodiment.

As shown in FIG. **7**, a portion of one side of a second nitride-compound semiconductor layer **12** is removed from p-type GaN contact layer **25** to n-type GaN clad layer **22** in a nitride-compound semiconductor light emitting device **50**. Removing the portion is performed by anisotropic reactive ion etching (RIE) using chlorine gas as an etching gas, for example.

A first electrode is provided on the portion of the p-type GaN contact layer **25**. A second electrode is provided on a portion of exposed n-type GaN clad layer **22**.

Al film is formed on the p-type GaN contact layer **25** by sputtering. The Al film is patterned by lithography to provide the first electrode **51**. A Ti/Pt/Au stacked film is formed on the n-type GaN clad layer **22** by sputtering. The Ti/Pt/Au stacked film is patterned by lithography to provide the second electrode **52**.

As a height of the nitride-compound semiconductor light emitting device **50** is equal to sum of t**1**, t**2** and t**3**, it is desirable to preliminarily adjust a thickness t**1** of the substrate **11** to fit to a target value. Further, the substrate **11** together with the first nitride-compound semiconductor layer **12** can be polished to be thinned. As a polishing process, after forming the first electrode and the second electrode, is a final process, so that the polishing process is not influenced with warpage.

As mentioned above, the method for fabricating the stacked nitride-compound semiconductor structure **10** according to the first embodiment includes forming the first protection film **31** and the second protection film **34**.

As a result, the deposition substances **32** attached to the first protection film **31** in forming the first nitride-compound semiconductor layer **12** can be simultaneously removed in removing the first protection film **31**.

Further, the deposition substances **36** attached to the second protection film **34** in forming the second nitride-compound semiconductor layer **13** can be simultaneously removed in removing the second protection film **34**.

Accordingly, when the nitride-compound semiconductor layers is formed both surfaces of the substrate, a method for fabricating the stacked nitride-compound semiconductor structure having easily removing the deposition substances can be obtained.

A case which the substrate is silicon, is described, however, other different substrate can be available. Sapphire (Al_2O_3) having thermal expansion coefficient being nearly 5.3×10^{-6}/K, silicon carbide (SiC) having thermal expansion coefficient being nearly 4.68×10^{-6}/K, zinc oxide (ZnO) having thermal expansion coefficient being nearly 3.9×10^{-6}/K or the like can be utilized.

A case which the first protection film **31** and the second protection film **34** are composed of silicon oxide, is described. However, it is not restricted to the above case, the same kind of films can be available. Silicon nitride can be selected as a material of the first protection film and the second protection film **34**.

A case which the first electrode **51** and the second electrode **52** are configured to the side of the second nitride-compound semiconductor layer **13**, is described as the nitride-compound semiconductor light emitting device. However, a case which the second electrode is configured to the side of the first nitride-compound semiconductor layer **12** can be available. FIG. **8** shows a nitride-compound semiconductor light emitting device **60** in which a second electrode is configured to a side of a first nitride-compound semiconductor layer.

As shown in FIG. **8**, a first electrode **61** is provided on a portion of the first nitride-compound semiconductor layer **12** in the nitride-compound semiconductor light emitting device **60**. A second electrode **62** is provided on entire first nitride-compound semiconductor layer **12**.

Further, as shown in FIG. **9**, a second electrode **72** may be formed on an exposed surface of a substrate **11** after polishing the first nitride-compound semiconductor layer **12** and the substrate **11**. In such process, as the surface of the substrate **11** is flat, the second electrode **72** is entirely formed on the surface. Accordingly, the electrode shape is simple, warpage is less influenced on the device. Further, the first electrode **71** is formed on a portion of the p-type GaN contact layer **25**.

As an advantage to provide the second electrode **62** at the side of the first nitride-compound semiconductor layer **12**, a size of the nitride-compound semiconductor light emitting device **60** can be smaller than a size of the nitride-compound semiconductor light emitting device **50**.

It is necessary that resistivity of the second nitride-compound semiconductor layer **13** and resistivity of the GaN layer **21** are lowered as much as possible by doping Si as an n-type impurity in the second nitride-compound semiconductor layer and the GaN layer **21**. It is desirable that the substrate **11** is composed of n-type Si with lower resistivity as less as possible.

Second Embodiment

A method for fabricating a stacked nitride-compound semiconductor structure according to a second embodiment is described by using FIGS. **10**A-**10**C.

Through the descriptions for the following embodiment, the same portions shown throughout the drawings will be denoted by the same reference numerals in the first embodiment. The second embodiment differs from the first embodiment in that the first protection film and the second protection film are composed of different material.

As shown in FIG. **10**A, a silicon nitride film as a second protection film **71** is formed on a first semiconductor layer **12**. The silicon nitride film is formed by plasma CVD, for example. A thin silicon oxide film as an underlying film is desirably formed to improve adhesion of the silicon nitride film.

As shown in FIG. **10**B, a silicon oxide film as a first protection film **31** is removed by a chemical solution with hydrogen fluoride, for example. In the removing process, as the silicon nitride film as the second protection film is not etched, a third protection film **35** as shown in FIG. **3**B is unnecessary.

As shown in FIG. **10**C, the silicon nitride film as the second protection film **71** is removed by a mixed chemical solution including phosphoric acid and nitric acid, for example, at a temperature of 180° C.

As mentioned above, the second embodiment has an advantage as follows. As the second protection film **71** is composed of silicon nitride, covering the second protection film **71** is unnecessary when the first protection film **31** is removed.

A case which the second protection film is composed of silicon nitride is described, however, it is not restricted to the above case. A non-crystalline silicon film, an aluminum oxide film or the like can be available. The non-crystalline silicon film means a poly-crystalline film, an amorphous silicon film or a film mixed with the both films.

A chemical solution removing the first protection film may have selectivity to the second protection film and a chemical solution removing the second protection film may have selectivity to GaN.

Further, the first protection film and the second protection film can be exchanged each other, so that the second protection film can be composed of silicon oxide.

While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without depart-

ing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

What is claimed is:

1. A method for fabricating a stacked nitride-compound semiconductor structure, comprising:

forming a first protection film on a second surface of a substrate, the substrate having a first thermal expansion coefficient, the second surface being opposed to a first surface of the substrate;

forming a first nitride-compound semiconductor layer on the first surface of the substrate, the first nitride-compound semiconductor layer having a second thermal expansion coefficient which is different from the first thermal expansion coefficient;

forming a second protection film on the first nitride-compound semiconductor layer, the second protection film and first protection film being a same material;

covering a surface and side surfaces of the second protection film with a third protection film, then using a chemical solution to remove the first protection film to expose the second surface of the substrate;

forming a second nitride-compound semiconductor layer on the second surface of the substrate exposed by removing the first protection film, the second nitride-compound semiconductor layer having a third thermal expansion coefficient which is approximately equal to the second thermal expansion coefficient; and

removing the second protection film to expose the first nitride-compound semiconductor layer.

2. The method of claim **1**, wherein

a first deposition substance is formed on the first protection film in forming the first nitride-compound semiconductor layer and the first deposition substance is simultaneously removed with the first protection film in removing the first protection film.

3. The method of claim **1**, wherein

a second deposition substance is formed on the second protection film in forming the second nitride-compound semiconductor layer and the second deposition substance is simultaneously removed with the second protection film in removing the second protection film.

4. The method of claim **1**, wherein

removing the first protection film and the second protection film are performed by isotropic etching.

5. The method of claim **1**, wherein

both the first protection film and the second protection film are composed of silicon oxide.

6. The method of claim **1**, wherein

the substrate is composed of at least one material selected from silicon, sapphire, silicon carbide and zinc oxide.

7. The method of claim **1**, wherein

the second nitride-compound semiconductor layer comprises a GaN layer, a first GaN clad layer, a multiple quantum well (MQW) layer, a second GaN clad layer, and a GaN contact layer stacked in order.

8. The method of claim **7**, wherein

the MQW layer comprises a plurality of a GaN barrier layers and a plurality of InGaN quantum well layers provided in alternation with the plurality of GaN barrier layers, and the uppermost layer of the MQW layer is an InGaN quantum well layer.

9. A method for fabricating a stacked nitride-compound semiconductor structure, comprising:

forming a first protection film on a second surface of a substrate, the substrate having a first thermal expansion coefficient, the second surface being opposed to a first surface of the substrate;

forming a first nitride-compound semiconductor layer on the first surface of the substrate, the first nitride-compound semiconductor layer having a second thermal expansion coefficient which is different from the first thermal expansion coefficient;

forming a second protection film on the first nitride-compound semiconductor layer, the second protection film and the first protection film being different materials;

removing the first protection film to expose the second surface of the substrate using a chemical solution having a selectivity for the first protection film over the second protection film;

forming a second nitride-compound semiconductor layer on the second surface of the substrate exposed by removing the first protection film, the second nitride-compound semiconductor layer having a third thermal expansion coefficient which is approximately equal to the second thermal expansion coefficient; and

removing the second protection film to expose the first nitride-compound semiconductor layer.

10. The method of claim **9**, wherein

the first protection film is composed of silicon oxide and the second protection film is composed of silicon nitride.

11. The method of claim **9**, wherein

a first deposition substance is formed on the first protection film in forming the first nitride-compound semiconductor layer and the first deposition substance is simultaneously removed with the first protection film in removing the first protection film.

12. The method of claim **9**, wherein

a second deposition substance is formed on the second protection film in forming the second nitride-compound semiconductor layer and the second deposition substance is simultaneously removed with the second protection film in removing the second protection film.

13. The method of claim **9**, wherein

removing the first protection film and the second protection film are performed by isotropic etching.

14. The method of claim **9**, wherein

the substrate is composed of at least one material selected from silicon, sapphire, silicon carbide and zinc oxide.

15. The method of claim **9**, wherein

the second nitride-compound semiconductor layer comprises a GaN layer, a first GaN clad layer, a multiple quantum well (MQW) layer, a second GaN clad layer and a GaN contact layer stacked in order.

16. The method of claim **15**, wherein

the MQW layer comprises a plurality of GaN barrier layers and a plurality of InGaN quantum well layers provided in alternation with the plurality of GaN barrier layers, and the uppermost layer of the MQW layer is an InGaN quantum well layer.

17. A method for fabricating a nitride-compound light emitting semiconductor device, comprising:

forming a first protection film on a second surface of a substrate, the substrate having a first thermal expansion coefficient, the second surface being opposed to a first surface of the substrate;

forming a first nitride-compound semiconductor layer on the first surface of the substrate, the first nitride-compound semiconductor layer having a second thermal expansion coefficient which is different from the first thermal expansion coefficient;

forming a second protection film on the first nitride-compound semiconductor layer, the second protection film and the first protection film being a same material;

covering a surface and side surfaces of the second protection film with a third protection film, then using a chemical solution to remove the first protection film to expose the second surface of the substrate;

forming a second nitride-compound semiconductor layer comprising a GaN layer, a first GaN clad layer, a multiple quantum well (MQW) layer, a second GaN clad layer, and a GaN contact layer respectively stacked in order on the second surface of the substrate exposed by removing the first protection film, the second nitride-compound semiconductor layer having a third thermal expansion coefficient which is approximately equal to the second thermal expansion coefficient;

removing the second protection film to expose the first nitride-compound semiconductor layer;

removing a portion of the second nitride-compound semiconductor layer, the portion extending from the GaN contact layer to the MQW layer, to expose a surface of the first GaN clad layer;

forming a first electrode on the GaN contact layer; and

forming a second electrode on the first clad layer.

18. The method of claim **17**, wherein

a first deposition substance is formed on the first protection film in forming the first nitride-compound semiconductor layer and the first deposition substance is simultaneously removed with the first protection film in removing the first protection film.

19. The method of claim **17**, wherein

a second deposition substance is formed on the second protection film in forming the second nitride-compound semiconductor layer and the second deposition substance is simultaneously removed with the second protection film in removing the second protection film.

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